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Chhetri, Ravi Kumar; Sharma, Anitha Kumari; Andersen, Henrik Rasmus

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DTU Environment
Department of Environmental Engineering

Technical University of Denmark

Chemical disinfection of combined sewer overflow (CSO) using performic acid

R. K. Chhetri, A. K. Sharma and H. R. Andersen


rakc@env.dtu.dk


akush@env.dtu.dk


hran@env.dtu.dk

Figure 1: Schematic representation of combined sewer overflows

Introduction

Combined sewer overflow (CSO) deteriorates the quality of receiving waters when it is discharged untreated, since CSO contain a variable mixture of rainwater, raw sewage, watershed runoff pollutants, variable pathogenic organisms.

According to European Union directive for bathing water the number of indicator organisms should not exceed 500 *Escherichia coli* (*E. coli*) and 200 Enterococcus per 100 mL water. Bathing water quality can be preserved by disinfecting the CSOs with a chemical disinfectant but the disinfection capacity of a chemical depends on concentration and contact time (Figure 2).

Disinfection of CSOs can be achieved in the existing sewer systems by adding a disinfectant in the beginning of the outlet pipe or before the detention tank. The organic peroxide performic acid (PFA) has emerged for disinfection of wastewater treatment plant effluents. PFA is strong disinfectants with a wide spectrum of antimicrobial activity and its degradation products are nontoxic and biodegradable.

In previous work we determined the potency and degradation kinetics of PFA in simulated CSO water and predicted that if the first flush is to be disinfected using PFA, 20 min contact time with 4 $mg\cdot L^{-1}$ is needed and 20 min with 2 $mg\cdot L^{-1}$ PFA is needed for continued overflow to maintain the indicator organisms within the EU guidelines.

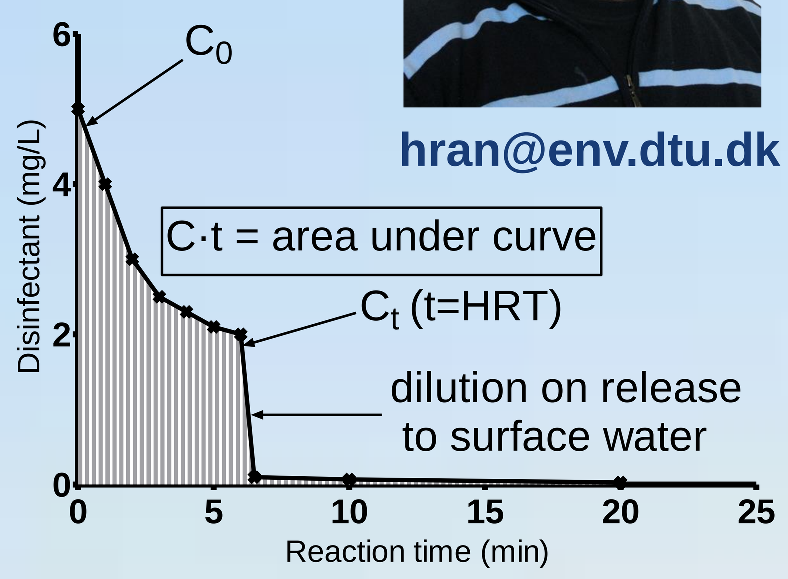

Figure 2: Disinfectant profile in proposed combined sewer overflow through retention basin or outfall pipe

Experiments

Pre-field experiment

A pre-field experiment on CSO collected from Skovshoved pump station was performed to verify the laboratory based prediction of the design of the first full scale experiment. CSO was collected automatically by the sampling device during the overflow event on 9^{th} August 2013. The CSO fractions were characterised chemically and used in spiking experiments to confirm the laboratory based proposal for a treatment strategy.

Field experiment

A CSO event at the sea outfall pipe structure for in Skovshoved (illustrated in Figure 3) was treated by a continuous dosing of PFA. CSO water was collected before and after the dosing point using automatic sampling device collecting samples in 20 min intervals. In order to replicate the 22 min retention time in the outfall, a pipe reactor was inserted into the sample stream from the treated water to the sampler where bottles were prepared with a PFA quencher to destroy the residual PFA at the time that simulated the mixing of the overflow into the sea.

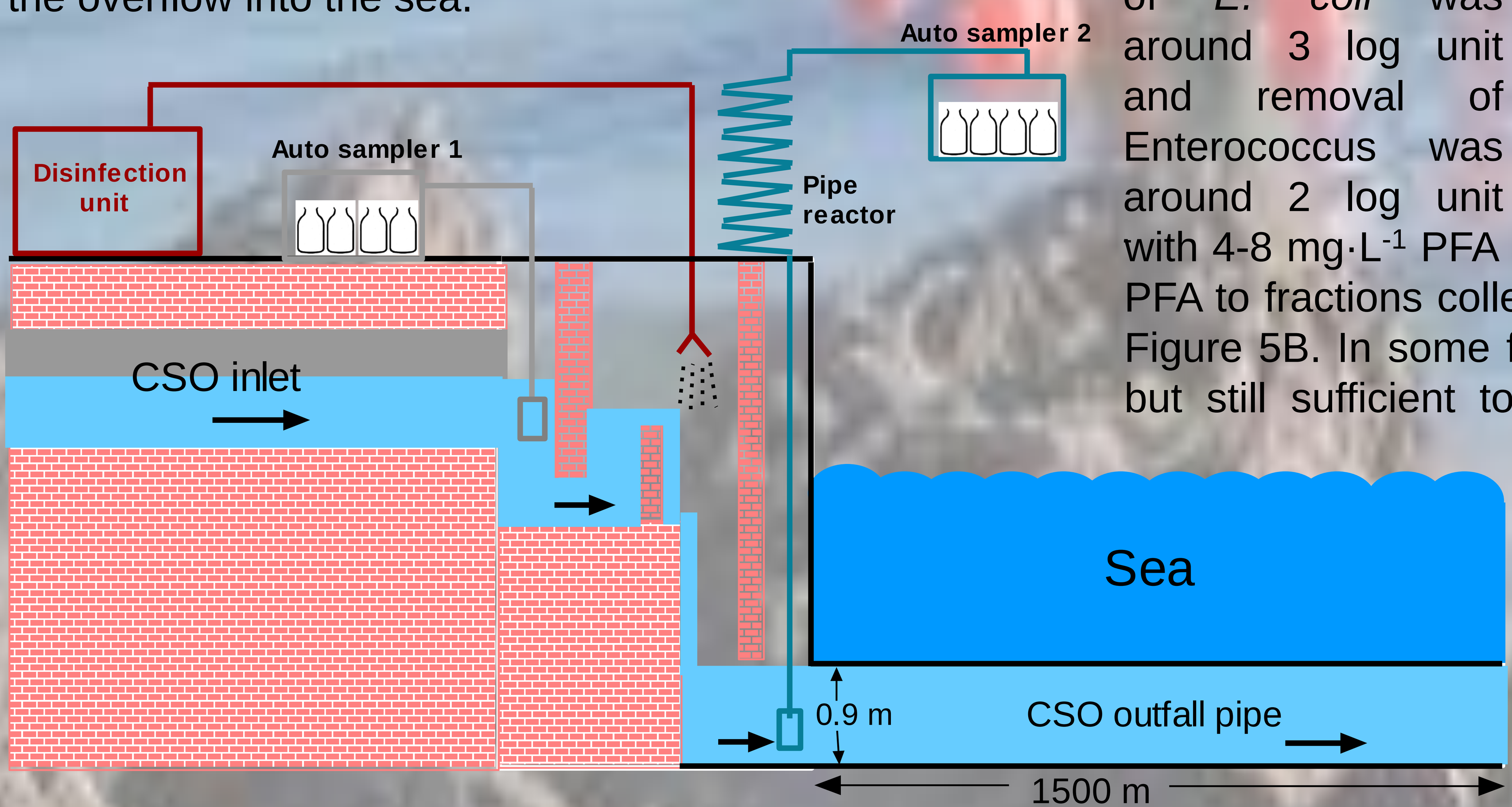

Figure 3: Schematic drawing of full-scale experiment at Skovshoved

Results

Residual concentrations from the intended treatment concentrations of PFA (4 or 2 $mg\cdot L^{-1}$ in first flush continued overflow) degraded in about 20 min (Figure 4A,B). Higher doses revealed that 8 $mg\cdot L^{-1}$ PFA disappeared in 30 min in the first flush and 4 $mg\cdot L^{-1}$ took about 60 minutes to disappear in typical overflow water. In the pre-field experiment removal of *E. coli* and Enterococcus was around 4 and 3 log unit, when 4 and 8 $mg\cdot L^{-1}$ PFA, respectively, was applied in first 3 fractions of CSO (First flush). Removal of *E. coli* and Enterococcus was >5 and >3 log unit with 2-4 $mg\cdot L^{-1}$ PFA applied in fraction 4 to 8 (Typical overflow; Figure 4C).

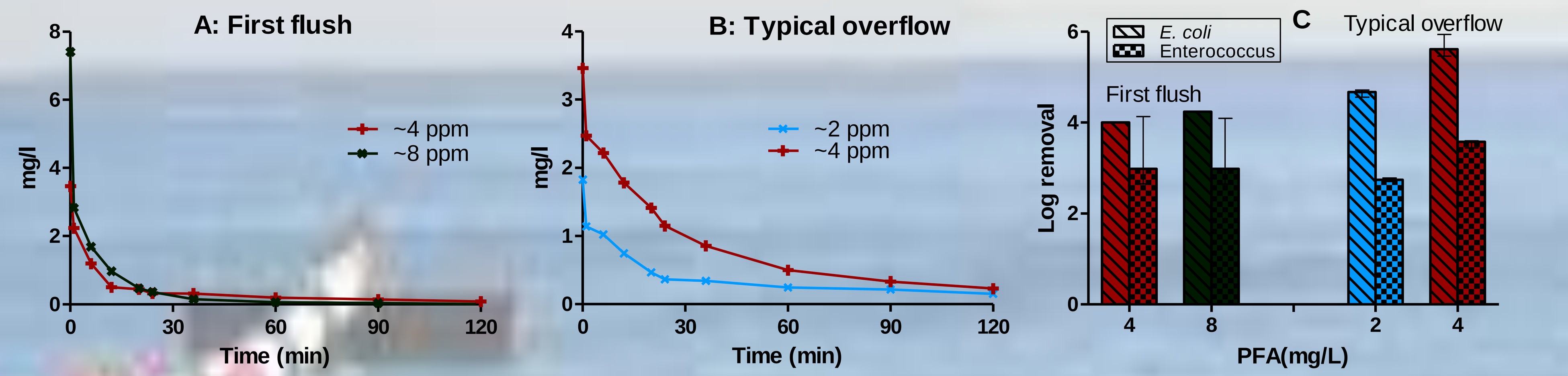

Figure 4: A) Concentration profiles of 4 and 8 $mg\cdot L^{-1}$ PFA added to a mixture of fraction 1 to 3 of CSO water (first flush) B) Concentration profiles of 2 and 4 $mg\cdot L^{-1}$ PFA added to fraction 3 to 8 of CSO water (typical overflow) C) Disinfection effect of PFA on indicator organisms in CSO water from mixing fractions and treated in the laboratory.

In the full scale experiment, removal of *E. coli* was around 3 log unit and removal of Enterococcus was around 2 log unit with 4-8 $mg\cdot L^{-1}$ PFA applied in fraction 4 to 15 (Figure 5A). Degradation profiles of PFA were verified by spiking PFA to fractions collected in the sampler before the dosing point (Auto sampler 1) as illustrated for fraction 7 in Figure 5B. In some fractions the degradation of PFA was slower than observed in our previous investigations, but still sufficient to give residual concentrations below the water quality criteria after initial dilution. The disinfection efficiency was confirmed by adding 1, 2, 3, 4 and 8 $mg\cdot L^{-1}$ PFA in the laboratory to the CSO fractions collected before the dosing point (Figure 5C).

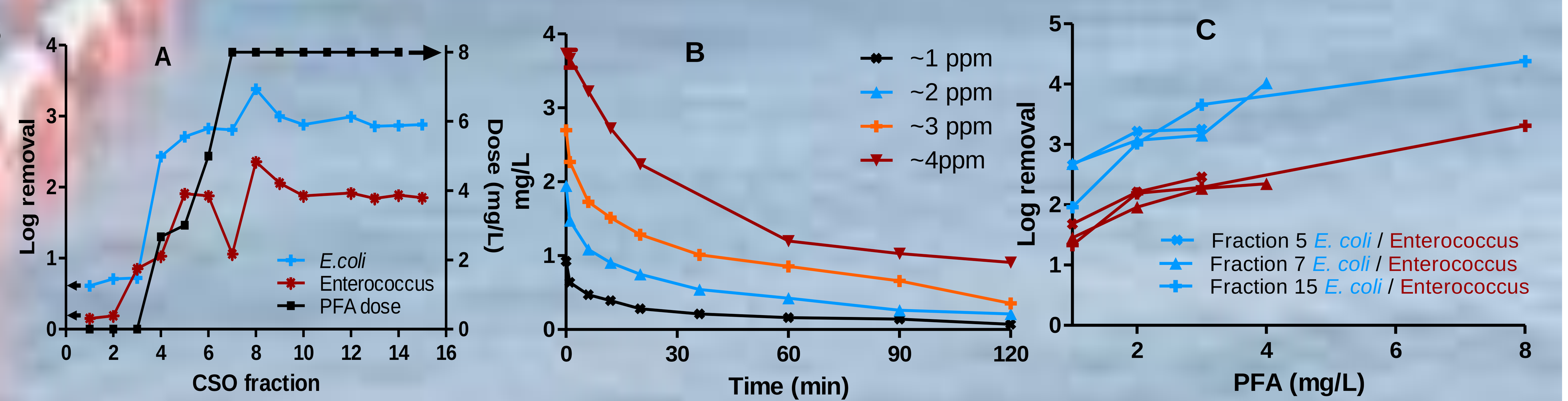

Figure 5: A) Disinfection effect and dose of PFA on indicator organisms in CSO treated in full scale. B) Concentration profiles of 1, 2, 3 and 4 $mg\cdot L^{-1}$ PFA added to fraction 7 of CSO water collected before the dosing point. C) Disinfection effect of PFA on indicator organisms in CSO-fractions treated in laboratory.

Conclusions

Effective disinfection of CSO water was achieved for the bathing water indicator organisms by applying moderate doses of PFA of 2-4 $mg\cdot L^{-1}$ while the PFA degraded sufficiently in first flush and typical overflow water to be diluted below the water quality criteria after initial dilution in the Sea (Øresund).